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# HOW TO MAKE CONVERTER STEEL CASTINGS

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BY ARTHUR SIMONSON  
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A comprehensive discussion of the methods involved in the manufacture of steel castings by the converter process.

This work is compiled from a series of articles by the author, written for and published by *The Foundry*.

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## CHAPTER I.

### CONSTRUCTION OF THE CONVERTER—ARRANGEMENT OF THE CONVERTER AND CUPOLA—CONVERTER OPERATING STATION—SPECIAL CUPOLA FOR MELTING THE IRON—HEATING THE LADLES—SAND GRINDING AND MIXING FOR STEEL FOUNDRY WORK.

IT will be the author's object, in this and succeeding chapters, to give a general idea of the science and art of making steel castings in a foundry equipped with the Tropenas system of steel-making. It is a mistake to think that the company operating a small converter plant can successfully compete in all lines of the casting business. There are, undoubtedly, branches where it cannot compete with the open-hearth and the malleable iron foundry. There are few things so light that they cannot be cast from the excessively hot steel made in the small converter, but for these tiny pieces, gray iron, malleable iron or brass are generally strong enough. On the other hand, for the very large pieces, say over 8 tons in weight, the open-hearth is probably cheaper, in America at any rate, though in England a plant operating five converters is successful in competition with the open-hearth and produces over 600 tons per month of miscellaneous castings of all analyses, and varying from less than a pound up to 10 tons.

The field of the small converter is ideally in the small and medium castings, and those calling for a specially high-grade material. It is an undisputed fact, that a well-handled converter of the Tropenas type produces a superior quality of steel, sounder, closer-grained and stronger than can be otherwise obtained. In automobile work, motor boats for gears, valves and levers, turbine work, gas engines and general machine work, converter castings are particularly desirable.

The realization of what can be done in the way of making light and intricate castings has led to the elaboration of engine and machine details in a remarkable way. A designer has no longer to take into consideration the possibility of not being able to get the castings he requires in steel. The small converter has made it possible to develop tremendous power engines occupying small space, and as proposition after proposition is put before

the founder and solved, he is beginning now to realize the possibilities of the process. The increasing number of plants being erected and the success with which they are meeting, testifies to the realization of the claims made for the side blow converter since its inception.

It is worthy of note that the open-hearth steel founders are now beginning to realize the usefulness of a small converter as an annex to their large furnaces, in this way being able to take care of absolutely any business that comes along, and thereby relieve the large furnaces of the tedious, costly necessity of making the small castings. There is today also at least one case of a malleable iron foundry installing a Tropenas converter. It seems probable that the time is near at hand when every open-hearth furnace operating on castings will have as an adjunct one or more converters, the idea would then be to make all the small castings with the converter and just enough of the larger ones to fill-in up to capacity. In dull times the entire output might be economically made with the converter.

We will now describe in detail a plant consisting of one two-ton converter and having a capacity of about 40 tons of castings per week. It consists of converter, converter blower and motor, pulpit or operating station, cupola, cupola platform and elevator, cupola blower and motor, ladles and ladle heating plant, sand grinder and mixer.

An analytical laboratory is also indispensable, and this has been made the subject of a special chapter. As for the foundry equipment, including cranes, flasks and miscellaneous rigging, it is the same for all foundries, no matter what process is used, but it may be well to make a few remarks on this subject in passing.

Electric traveling cranes are now almost exclusively used with wall or jib cranes as accessories. All foundry buildings are, or should be of steel construction with ample lighting facilities. Up-to-date plants are provided with heating and ventilating systems so that in summer, air from outside can be distributed through the building, and in winter it is passed through steam coils. The heating of foundries is a very important matter. If the sand is allowed to freeze it will cause endless trouble, particularly if green sand castings are made. The artificial lighting of a foundry for night work is a problem requiring considerable attention. The atmosphere in a foundry is often smoky and always very dusty, and it requires a very good distribution of powerful lights to enable the men to work when necessary, at night as well as in the day time. The ovens for drying molds should be as large as possible, and their trucks designed of such type that the heating of axles and bearings will not affect their operation. Flasks, chains and general tackle should be as heavy as is convenient to handle. The less risk taken the better—and the foundry business has enough of them under the most favorable conditions.

The writer is of the opinion that any amount of money judiciously expended on the special tackle and rigging in the foundry pays a good dividend in safety, speed and economy.

THE CONVERTER.

The converter is of 2 tons capacity, that is to say, it is capable of turning out at each operation approximately 2 tons of steel. In this chapter it will be considered as a machine only; its metallurgical side will be dealt with in a succeeding chapter. The illustrations, Figs. 1, 2, 3 and 4, will give a good idea of the general appearance of the converter. Fig. 1 shows the arrangement of the steel converter and the cupola; Fig. 2 shows the

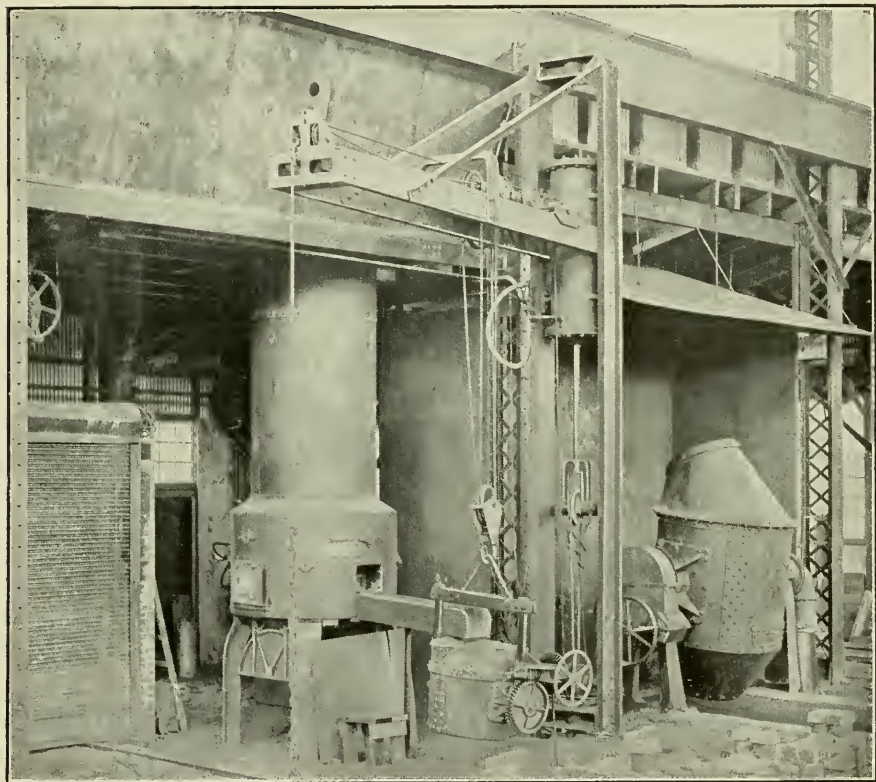


FIG. 1—ARRANGEMENT OF STEEL CONVERTER AND CUPOLA. THE METAL FROM THE CUPOLA IS CONVEYED TO THE CONVERTER BY A JIB CRANE

converter tilted while the metal is being poured into the vessel for the blow; Fig. 3 shows the converter in operation and Fig. 4 shows the converter tilted to empty the slag after the metal has all been poured out.

The shell of the converter is 5 feet in diameter and is made of  $\frac{5}{8}$  inch steel plates, perforated with  $\frac{3}{4}$ -inch holes spaced 8 inches center to center to allow the steam to escape when drying the lining. The amount of floor space occupied by the converter is about 16 feet square and the head room

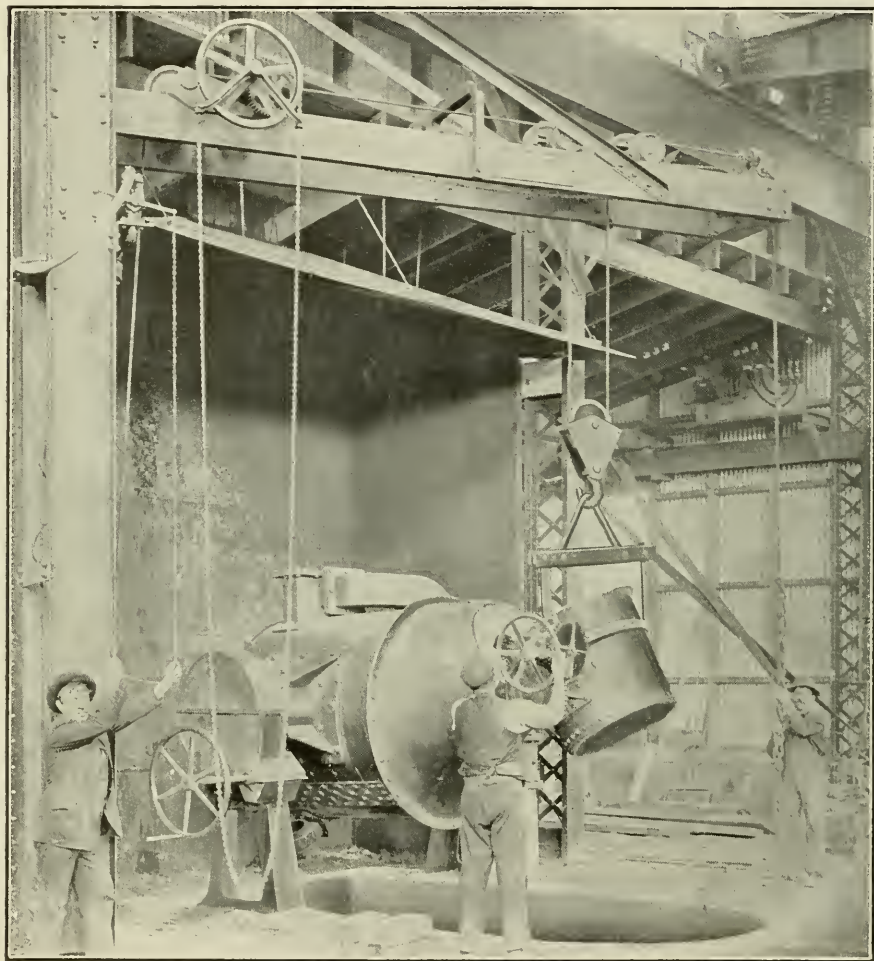


FIG. 2—POURING THE METAL INTO THE CONVERTER.

required is about 18 to 20 feet to enable the whole of the flame, which comes out of the mouth, and which constitutes the means for judging the condition of the steel, to be seen at all times.



The converter is supported on steel trunnions, one of which is hollow and forms a duct for the air, connecting with the blast box at the back of the converter. This enables the air to be kept on continuously while the position of the converter is being changed. The blast box is double, and air can be admitted to either side separately, or in varying proportions. This is partly shown in Fig. 6, which is a section of the converter, both vertical

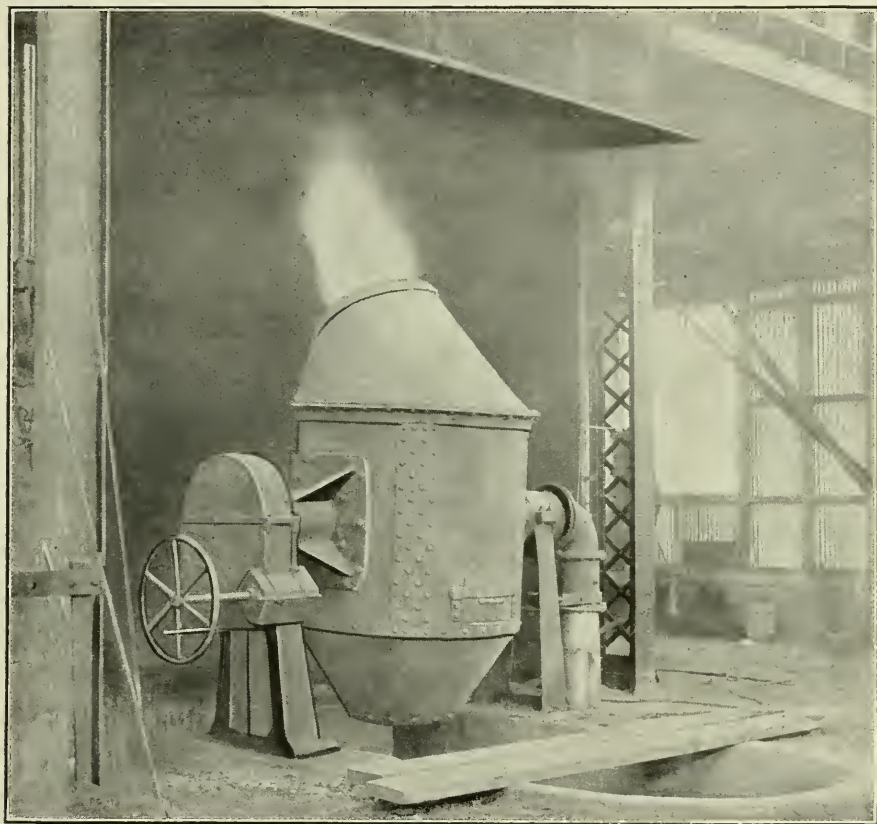


FIG. 3—THE CONVERTER IN OPERATION

and horizontal, showing the arrangement of the tuyeres, the level of the bath and the approximate position of the vessel while the blow is being made. The other trunnion is extended and carries a worm wheel which, through suitable gearing, is connected to a 4 horsepower motor. A hand wheel is also provided for making small movements of the vessel as required



from time to time. The electric motor has been generally adopted for tilting the converter, although any means may be employed, and plants are in operation in various places using compressed air, steam and hydraulic power. This is a mere detail and depends on circumstances. The converter is firmly bolted to pedestals, which are sufficiently high to allow the converter to make a complete revolution if necessary. This is advisable for facility in emptying the converter, and also to enable the whole of the metal to be poured out before the vessel is too low for the men to hold the ladles.

The covers of the blast boxes are fastened on by means of keys, for quick removal to clean out a tuyere or to set the converter at the commencement of a blow. The upper box is fitted with a pipe having an independent valve so that it may be shut off entirely if desired, or any required amount of blast admitted according to the conditions that arise as the blow proceeds. The lining of the converter will be dealt with in the next chapter.

#### CONVERTER BLOWER AND MOTOR.

The blower is of the positive pressure type, and must be capable of maintaining a constant pressure up to 4 pounds per square inch through the area of both sets of tuyeres, which consist of seven in the lower row,  $1\frac{3}{8}$  inches in diameter, and seven in the upper row about  $1\frac{1}{2} \times 5\frac{3}{8}$  inches. A water-jacketed blower running at about 400 revolutions per minute, is commonly used and is satisfactory. Blast may be supplied by a blowing engine, but is not so satisfactory, as the pulsations of the engine, unless absorbed by a very large receiver, are manifest in the flame and interfere with the observation of the reactions. A rotary blower is best on this account as it gives a practically constant stream of air, and makes the flame perfectly steady, at least as far as outside influences are concerned. The blower should be direct-connected to a motor of about 75 horsepower; no less is advisable, as it is better to have a little power in reserve and not run the risk of the circuit breaker flying out all the time, for when this happens, it always seems to occur at a critical time in the blow and may lead to clogging of the tuyeres, loss of time and possibly disaster to the blow. The blower should be placed close to the converter, but not too close, as a fair length of the 12-inch air main serves as a reservoir and gives elasticity to the blast. Elbows in the pipe should always be avoided.

#### OPERATING STATION.

This is the place where the operator stands to watch the progress of the blow and to tilt the converter according to the different requirements of charging, pouring, etc. It is better to place this at one side of the vessel,

about 20 feet away, if possible, so that the heat will not inconvenience the operator and that he may see the whole of the flame. It is not advisable to place the pulpit across the building as in this case the flame is fore-shortened, and it is not possible to see the smoke, sparks, etc., so clearly. The pulpit contains the controller for tilting the motor, the lever of the by-pass valve to regulate the pressure of air going into the converter, a signal whistle to the blower room to signal the engineer when to start and stop the blower, and a mercury pressure gage. The engineer, on receiving the signal of two short blasts, starts the blower at full speed and maintains it at this speed all through the blow. Variations of pressure are then obtained by the operator opening or closing the by-pass and allowing more or less air to escape through a pipe leading to the outside. The blast gage, read-

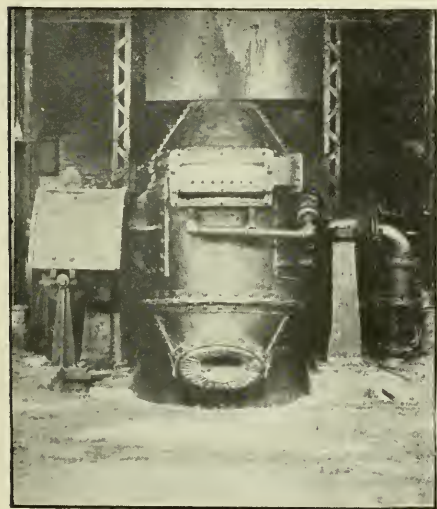


FIG. 4—CONVERTER TILTED TO EMPTY THE SLAG AFTER THE METAL HAS BEEN POURED OUT

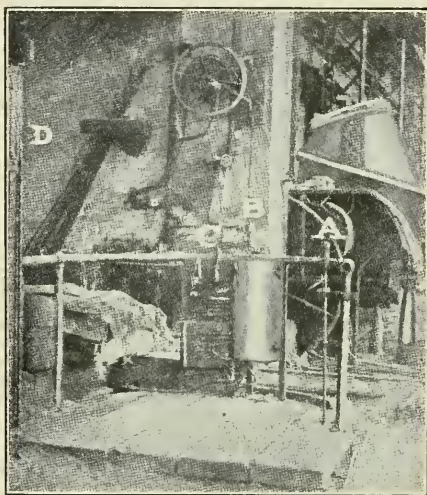


FIG. 5—THE CONVERTER OPERATING STATION

ing in pounds, is attached to the blast main between the blower and the by-pass. Fig. 5 gives a view of the pulpit; *A* is the lever of the by-pass valve; *B* is the controller of the tilting motor; *C* is the whistle, and *D* is the mercury gage.

#### CUPOLA.

There has been a great deal of discussion as to the best type of cupola for the Tropenas converter. It is largely a matter of opinion. The fact

is, that it is required to melt about 5 tons per hour of a charge consisting oftentimes of as much as 50 per cent of steel scrap, to melt it hot, and to be capable of running very long heats, sometimes as long as eight or nine hours. Any cupola that will meet these conditions is suitable. It must

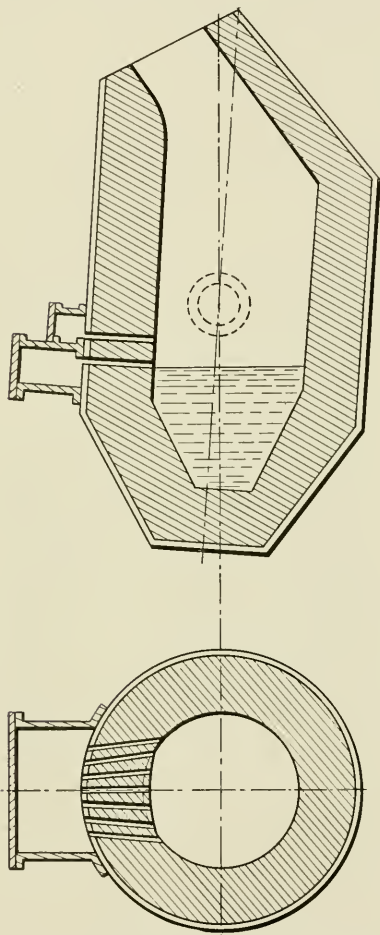


FIG. 6—VERTICAL AND HORIZONTAL SECTIONS OF STEEL CONVERTER.



FIG. 7—SPECIAL CUPOLA FOR MELTING IRON FOR THE CONVERTER

be remembered that in melting low phosphorus stock such as is used in steel-making, a hot melting cupola is necessary, and facilities must be provided for taking care of a large quantity of slag, as considerable flux is used to keep the sulphur as low as possible. There has also been considerable

discussion as to the desirability of having a cupola large enough to melt the total charge for one blow at one tap, or getting it at two taps. After long experience, the author has come to the conclusion that a somewhat special cupola is the best, and this after using almost every kind that could

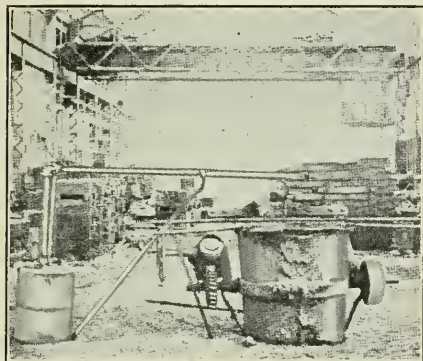


FIG. 8—HEATING A LARGE LADLE  
WITH AN OIL BURNER

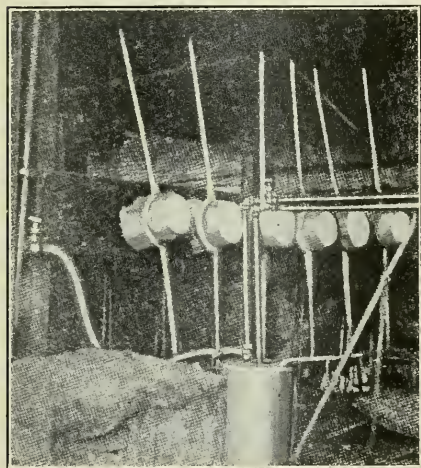


FIG. 9—METHOD OF HEATING HAND  
LADLES

enough to carry a day's run of melting stock, and should be figured to carry not less than 500 pounds per square foot. It should be roomy, and provided with facilities for good ventilation as a good deal of smoke from the

be mentioned. The writer's idea of a suitable cupola is one built on the lines of a blast furnace, with a bustle pipe and pendant tuyeres, such as is illustrated in Fig. 7. The bustle pipe or blast box must be ample in size in order to maintain equal pressure at all of the six tuyeres. The advantage of this type of cupola is that the tuyeres are always clean, and if any slag or iron runs into them it runs out again without going into the blast box.

The cupola should be about 54 inches in diameter, lined with two rows of  $4\frac{1}{2}$ -inch bricks, giving an inside diameter of 36 inches. The tuyeres should then be placed so that the slag hole, which is 6 inches lower than this, will be sufficiently high to allow of the required amount of iron being tapped out when it has melted up to this height. In this way the cupola will be kept entirely free from slag, the tapping spout will be kept clear through a long heat, and there will be little risk of scaffolding. A blast pressure of from 10 to 14 inches of water should be maintained.

#### CUPOLA PLATFORM AND ELEVATOR

The cupola platform should be higher than is usual in iron foundries, as it should be arranged to take care of a height of not less than 13 feet of cupola from bottom plate to charging door. The platform should be strong



converter finds its way up there and at times it is a very undesirable place to work. The elevator, preferably electric, should have a large platform and should be capable of lifting about 3 tons at a time at a speed of about 60 feet per minute.

#### CUPOLA BLOWER AND MOTOR.

Any of the accepted types of cupola blowers are satisfactory, whether fan or pressure blower, but they should be designed to give ample volume, on account of the high tuyeres and the large percentage of steel scrap used in the charges. The motor is of about 25 horsepower.

#### LADLES.

The Tropenas converter makes such exceedingly hot steel that it can all be poured over the lip of the ladle, bottom-pour ladles not being necessary. For pouring small work such as is made in snap molds, hand or bull ladles holding about 150 pounds, are commonly used. They are about 13 inches in diameter at the top and are lined to a thickness of  $1\frac{1}{2}$  inches. The shanks are about 7 feet long, and have one double end for the man

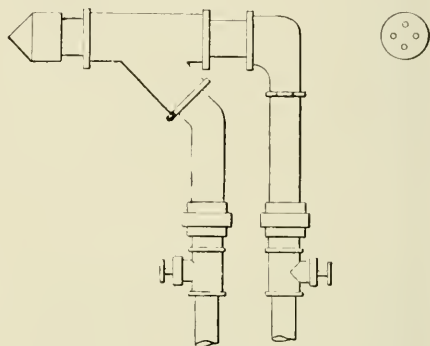


FIG. 10—OIL BURNER FOR HEATING LADLES

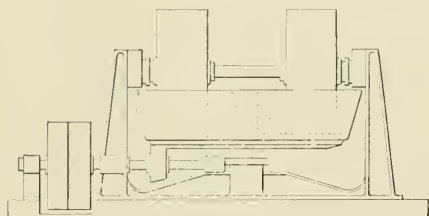


FIG. 11—ROLLER TYPE GRINDER FOR GRINDING AND MIXING THE MOLDING SAND

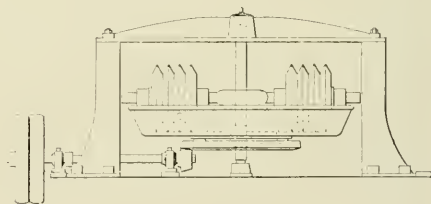


FIG. 12.—TYPE OF GRINDER PREFERRED BY THE AUTHOR

who is to do the pouring and a single end for the helper. The crane ladles are the same as iron foundry ladles, except that they are generally a little smaller in diameter in proportion to their height, to reduce the loss of heat by radiation. They are preferably geared with pin spur gearing instead of



worm and wheel, as this gives a greater control, steadier flow and less possibility of a drop of the ladle when the gearing is worn.

#### LADLE HEATING FURNACE.

Ladles are generally heated to redness before filling with steel. In the case of the large ladles, this is done either by inverting them over an oil-burning furnace, or introducing an oil burner through a portable cover placed over the top of the ladle. The latter is illustrated in Fig. 8.

A device for heating small ladles, arranged by the author, is shown in Fig. 9. It consists of a series of small oil burners placed side by side, spaced about 18 inches apart from center to center, and a vertical plate with a two-inch hole opposite each burner, through which the flame passes and fills the bull ladle, which is reared against the plate. In this way any number of ladles can be heated, according to the length of the plate, or, if required, one ladle can be heated white hot in 10 minutes. It takes up very little floor space, is clean and easy to operate. Fig. 10 is a detail of the burner.

#### SAND GRINDER AND MIXER.

A grinder of the roller type is generally used. The usual type of mixer is illustrated in Fig. 11, but the author prefers the type shown in Fig. 12. In this mixer, while a perfect mixture of the sand is obtained, there is not so much crushing of the grains, and the resulting sand is more open, as is desirable in steel molding. This mixer is also very speedy in mixing sand, making it "strong" in much less time than the heavy roller grinder.

## CHAPTER II

### LINING THE CONVERTER—KIND OF BRICK USED—LIFE OF THE LINING— CONSTRUCTION OF WOOD FORMS USED FOR LINING THE CONVERTER

**I**N attempting to give a detailed description of the operation of a Tropenas plant, it is realized that no amount of written instruction will enable one not thoroughly acquainted with steel-making in general, to produce any kind of castings, to say nothing of the high grade of work that is called for today. The only way to learn how to operate a converter plant is to spend a long time in company with one who has had considerable experience and is perfectly familiar with the reactions that take place. It is true that when the converter was first introduced the pioneers had no one to instruct them, but it would be much too costly for all to learn by the same method. It is true, indeed, that after being under personal instruction and seeing a great many blows made, conditions may arise, after the operator is left to himself, which may puzzle him, and cause him to forget some of the principles that have been drilled into him. It is only by the strictest attention to details that success is achieved, but this is true of all trades, not only steel-making. An unsuccessful foundry business resembles a Kansas cyclone in its certainty of disaster—quick and complete. A foundry that is not watched at every point can absorb money as fast as Rockefeller can pour it in, as many a poor man has discovered. The essentials to success are shrewdness, watchfulness and science.

#### LINING OF THE CONVERTER.

There are two or three ways to line the converter, and they are all equally good, the factors determining the use of any one being convenience and local conditions. It may be lined with special blocks, which, while expensive, make the time occupied in repairs much less, this being often a very serious matter when the converter needs repairing and orders are waiting fulfillment. The chief drawback to the use of special blocks is that in making repairs, a large amount of good brick has often to be cut away to make room for the new ones. A sand lining, rammed in to shape, may be used and is probably as good and cheap as any, provided the proper

grade of material is available. The third way is to use the ordinary shapes of furnace brick. This is probably the most common way and will be described in full detail, as it probably calls for more explanation than the others. Whatever material is used, it is necessary that it should be as refractory as possible, and nothing should be used in the way of brick that has been burnt at a lower temperature than is necessary to turn over a 3,500-degree Seger cone. This means about 95 per cent silica and almost absolutely free of lime and magnesia. In the case of the ganister mixture,

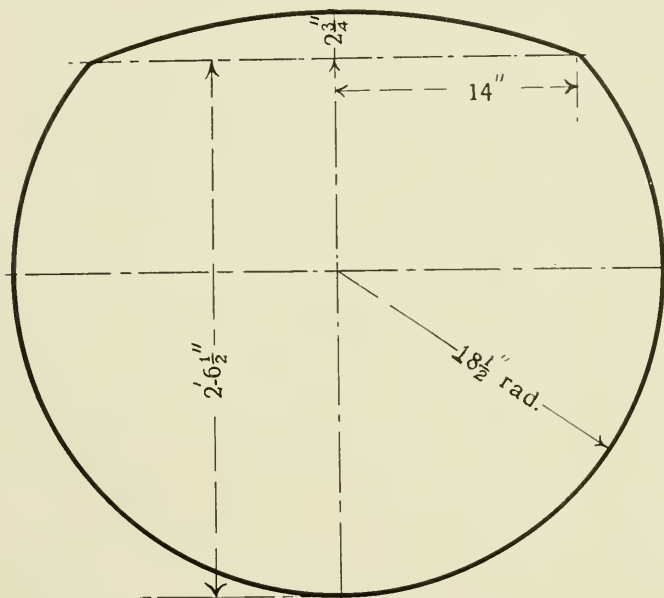


FIG. 13—WOOD FORM USED FOR LINING THE CONVERTER

the very best quality of silica clay must be used and in order to cause it to set very hard, it may be mixed with weak lime water.

#### LINING THE CONVERTER WITH SILICA BRICK.

The bricks used are the square,  $9 \times 4\frac{1}{2} \times 2\frac{1}{2}$  inches, with the arch  $9 \times 4\frac{1}{2} \times 2\frac{1}{2} \times 1\frac{1}{2}$  inches, the wedge,  $9 \times 4\frac{1}{2} \times 2\frac{1}{2} \times 1\frac{1}{2}$  inches, and a special wedge used in the mouth,  $9 \times 4\frac{1}{2} \times 2\frac{1}{2} \times 1$  inches. A small quantity of split brick is also required. This is a rectangular brick one-half the thickness of the ordinary square.

Two or three rough wooden forms should be prepared, having dimensions as shown in Fig. 13. They are made by sawing out boards for top and bottom, 2 inches less in dimensions each way, and then nailing 1-inch strips on the edges. The forms are 18 inches high. Set the converter in a vertical position by means of a plumb line, and then commence the lining operations by laying ordinary firebrick in the circular bottom until a level of about 26 inches below the center of the lower tuyere slot in the bottom wind box is reached. Break all joints and set alternate courses at right angles. Use ordinary firebrick of good quality for this part of the operation.

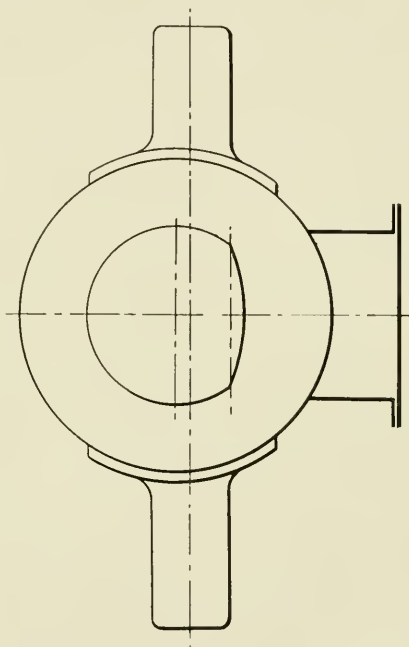


FIG. 14—ONE OF THE WOOD FORMS SET  
IN THE CONVERTER

ation, as they are less friable than the silica brick, and do not come into direct contact with the heat. The cement used may be made of one-half each, high-grade silica clay and crushed silica rock. For grouting in the courses after laying, this cement may be thinned with water.

The next step is to set one of the forms. The illustration, Fig. 14, shows the location of this. It will be seen that the circular part of the form is eccentric with the circular shell of the converter, and the part of larger radius, which gives the conformation of the face of the tuyeres, is set so that a line joining the ends of the arc is parallel to the center line

of the trunnions. A course of arch brick on end is laid around the form, and outside of this, a row of ordinary firebrick backing, and the remaining space between brick and shell is rammed-in with ganister. This procedure is continued until a level,  $2\frac{1}{2}$  inches below the center of the slot in the shell referred to is reached.

This brings us to the most important point in the lining, namely the setting of the tuyeres. Upon this depends a great deal of the assurance of success in the subsequent manufacture of the steel. The tuyeres, both individually and as a whole, must be set absolutely level, both in a direction parallel to their length and also in a direction at right angles to this. In other words, the tuyeres must all be in exactly the same plane. Fig. 15 shows the tuyeres grouped together and it will be noted that for convenience, they are numbered No. 0 in the center, No. 1 for the first tuyere on each side, then No. 2 and No. 3, respectively. The higher numbers diverge more from the center than the lower numbers, and the whole sys-

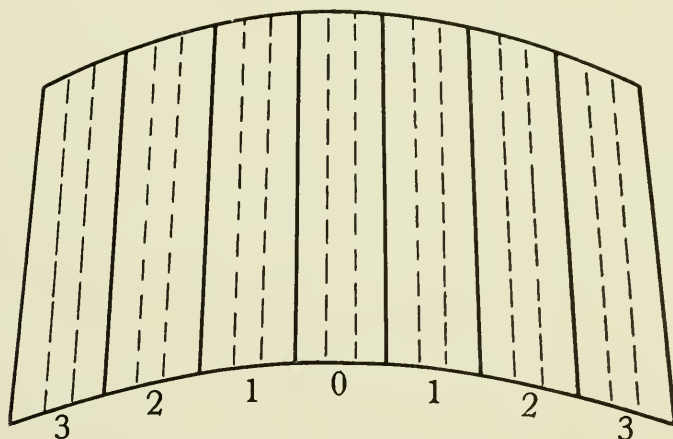


FIG. 15—TUIERE BLOCK.

tem is symmetrical. These tuyeres are made of the very highest grade of silica material available, and they are burnt at a very high temperature as they are subjected to the greatest amount of wear and tear and the greatest amount of chemical action. In setting the tuyeres, it must be borne in mind that the holes must be leveled and not the outside of the bricks, as the outside may be warped to some extent.

Round iron bars, of smaller diameter than the tuyeres, should be inserted in the holes and the leveling done on the protruding ends of these, this being the only way that accuracy can be insured. Together with this leveling, care should be exercised that the tuyeres come opposite the slot in the shell communicating with the lower wind box to allow of an



unrestricted passage of the air into the converter and the possibility of cleaning out any slag or iron that may inadvertently get into the tuyeres. After being satisfied that the lower tuyeres are correctly set in every particular, the upper tuyeres are set directly on top of them. The upper wind box has a slot corresponding with the lower one, and the rectangular openings in these tuyeres should be in line with it. It is not necessary to use the same care in setting these tuyeres, as they are merely combustion tuyeres and do not at any time approach the surface of the iron. They are numbered similarly and have the same conformation as the lower tuyeres. The body of the converter is then lined up to a point about 2 feet below the top of the cylindrical part of the shell, at which point the wooden forms may be dispensed with. Be sure to leave no open spaces between the bricks, and grout all the joints well with thin grout. From this point a certain amount of mechanical skill is required in setting the brick, as it is largely a matter of hand and eye. It is not an easy matter to describe, nor is it an easy matter to accomplish, but the principle is to overlap each course from this point up the cone until the lining terminates at the mouth of the converter in a circular opening, 15 inches in diameter. The last two rows in the mouth may be made with the special wedge brick mentioned. After the lining is completed, the wooden forms may be burnt out. The bottom is then built-up with pure silica brick until a depth of from 16 to 17 inches below the bottom edge of the tuyeres is reached. This corresponds very closely to a capacity of 2 tons. The lining being now complete, a wood fire is started, the blast valve being shut-off and all covers have been removed from the wind boxes. If the blast valve from the blower is left open, it may happen that gas will accumulate in the pipe and cause an explosion, which may be more or less serious. In describing the lining of the converter, nothing has been said of the manhole door in front of the converter, which some operators use all the time and others have discarded. It is most useful in making repairs, enabling the converter to be cooled off very rapidly and also forms a convenient way of handing in to the bricklayer his supplies of bricks and cement. When this is used, an arch should be built around the opening in the shell and filled in afterwards; then when the manhole is punched out, the remainder of the lining is undisturbed.

#### LIFE OF THE LINING.

It is almost impossible to give definite figures as to the life of furnace linings. So much depends on shop practice and quality of materials, that it is impossible to make an accurate estimate. For instance, if a furnace is run every other day and repaired every other day, it will last longer than if run daily for the same number of blows. There is a limit to the amount of patching that can be done, and if it is done before it is too late, it will not be necessary to cut away a lot of good brick in

order to make extensive repairs. The inner row of brick, that is the silica part of the lining, should never be allowed to be entirely penetrated. By making repairs at as short intervals as possible and preserving the original lines of the furnace, the life of linings will be preserved indefinitely, and the blows will be much more regular and uniform. The parts that are most subject to corrosion are the regions immediately surrounding the tuyeres, and at the base of the upper cone where the metal lies when the converter is in the pouring position. When repairing the tuyeres, bars slightly less in diameter than the holes should be inserted and ganister rammed around them and allowed to dry with the bars in place. / By careful attention to repairs as many as 150 and even 200 blows can be made in a converter before it is necessary to renew the tuyeres, and up to 1,000 blows before it is necessary to entirely reline. A new set of tuyeres can be inserted in about three hours. A considerable amount of the depreciation of the lining is caused by crushing and spalling. Silica brick has a very high coefficient of expansion and the alternate heating and cooling of the lining causes it to crush at one time and spall off at another. The expansion is so great that the bolts holding down the upper cone sometimes pull apart, the heads flying a considerable distance. After a converter has been newly lined, these bolts should be loosened to allow the expansion to take place.

## CHAPTER III

### ANALYSIS OF THE IRON TO BE CONVERTED INTO STEEL—CALCULATION OF THE CUPOLA CHARGE—GRAPHIC METHOD OF FIGURING THE CUPOLA CHARGE

THE metal that is put into the converter to be converted into steel must be of a definite composition within certain limits. Before reaching the converter it has to be melted in a cupola, where certain losses take place. These losses have to be taken into consideration when figuring the charges. In specifications for steel castings a limit is generally set for the content of sulphur and phosphorus, and as in no acid furnace can this percentage be reduced, it is necessary to provide raw material sufficiently low in these elements to meet the specifications. In this respect it is exactly the same as the open-hearth practice. The analysis of the metal before blowing must be:

	Per Cent
Silicon .....	1.80-2.10
Manganese .....	0.60-1.00
Carbon .....	about 3
Sulphur and Phosphorus.....	as low as possible

The cupola charges are made up of pig iron and steel scrap. The steel scrap generally consists of the heads and runners, scrap and defective castings from previous heats. Outside scrap is so uncertain in its composition that it is unsafe to use it. As a rule, the best way is to arrange to melt in the cupola just the amount of scrap made in average daily practice. If a surplus accumulates, the percentage can be temporarily increased, and if a shortage occurs, the amount can be cut down. Ordinarily, with a satisfactory operation of the plant, about 20 to 25 per cent of steel scrap can in this way be carried in the cupola charges. The flux used in the cupola consists of limestone or oyster shells, and the coke is 72-hour coke with sulphur, 0.75 per cent or thereabouts.

#### CALCULATING THE CUPOLA CHARGE.

There are two ways in which this may be done, a graphic way and an arithmetical way. In figuring out the charge the two elements, which are closely controlled, are the silicon and manganese, and particularly the sili-

con. This element is always figured first. As regards sulphur and phosphorus, it is understood that they are as low as possible in the raw materials so that after that point has been settled, they may be neglected. Carbon, that is, total carbon, is practically the same in all grades of pig iron used, and may be neglected on that account, as it will be practically uniform anyway. The relation of the combined carbon to the graphitic does not make any difference, as after the first few minutes' blowing, it will all be in the combined state.

The first thing to be decided is the amount of scrap it is proposed to carry in the charge. Of course there are cases where the grade of pig iron available will place a limit on the amount of scrap that may be used. If the pig iron is all high silicon, it will be imperative to use a high percentage of scrap to cut down the silicon to the required amount. If the pig iron is low in silicon, it may be possible to use only a very small proportion of scrap. But for the purposes of this example we will suppose that the conditions are ideal, that we have the correct kinds of pig iron and are able to carry any reasonable amount of scrap. As stated above, it is wise, all things being equal, to confine the scrap to that made in the plant, and in an ordinary way this will amount to say, from 20 to 25 per cent. Let us assume that we have two brands of iron analyzing:

	No. 1 Per Cent.	No. 2 Per Cent.
Silicon .....	3.50	2.00
Manganese .....	0.25	1.50

Let us assume that our steel scrap averages silicon, 0.25 per cent and manganese, 0.75 per cent. Let us also assume that we will carry 25 per cent of scrap.

#### PROBLEM.

In a 100-pound charge, what quantities of the above No. 1 and No. 2 pig irons and steel scrap will give a mixture with an analysis of say, silicon, 2.00 per cent, and manganese, 0.80 per cent? We know how much steel scrap we are going to carry and will figure the silicon first, as follows:

$$\begin{aligned}
 (\text{Weight of scrap} \times \text{per cent silicon}) + (\text{weight of pig iron} \times \text{per cent silicon}) &= (\text{1,000 pounds mixture} \times \text{200 per cent silicon}) \\
 (250 \times 0.25) + (750 \times X) &= 2000 \\
 62.5 + 750X &= 2000 \\
 X &= 2.5833
 \end{aligned}$$

The next question is: In a charge of 750 pounds, how much pig iron, No. 1, 3.50 per cent silicon, and how much pig iron, No. 2, 2.00 per cent silicon, will give a mixture containing 2.5833 per cent silicon?

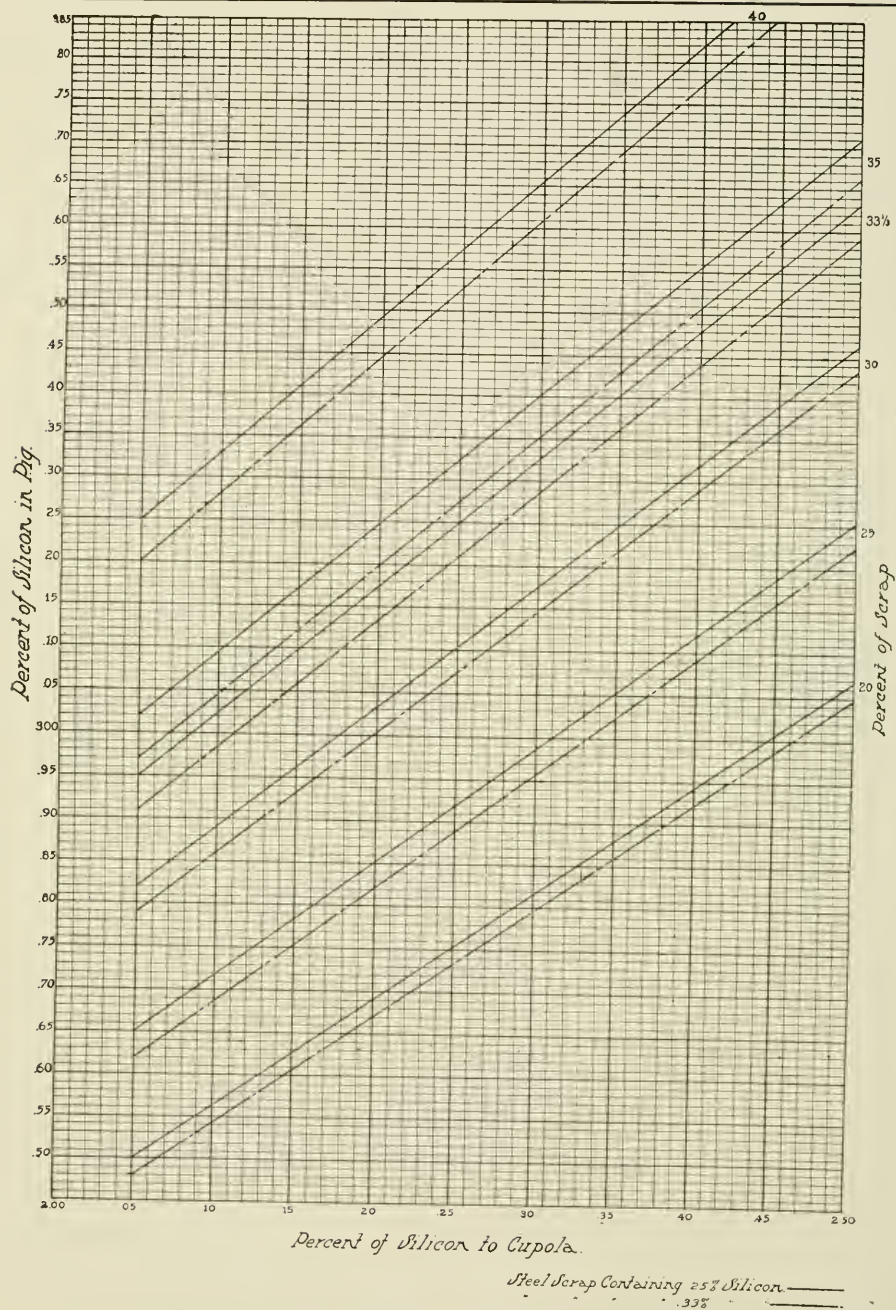


FIG. 16—GRAPHIC METHOD OF FIGURING CUPOLA CHARGES



Let X equal the weight of pig iron No. 1 containing 3.50 silicon, then  $(750 - X)$  represents the weight of pig iron No. 2 containing 2.00 silicon, and  $(X \times 3.50) + (750 - X) 2.00 = (750 \times 2.5833)$   
 $3.50 + 1500 - 2X = 1937.5$   
 $X = 291.6$

The quantity of No. 1 pig iron required is, therefore, accurately 291.6 pounds, and of No. 2 is 458.4 pounds. In round figures, the amounts of our cupola charge of 1,000 pounds would therefore be:

	Pounds
No. 1 pig iron .....	290
No. 2 pig iron .....	460
Steel scrap .....	250

Let us check this over to see if it is correct:

$$(290 \times 3.5) + (460 \times 2.00) + (250 \times 0.25) = (1000 \times 2.00)$$

$$1015 + 920 + 62.5 = 1997.5$$

This figures out as closely as it is possible to weigh pig iron. The above calculations cover the silicon only, and while they seem bulky, they have been put down in detail to make it perfectly plain. As a matter of fact, the calculations are made in a very few minutes. We must now see how these weights will result in content of manganese:

$$290 \text{ pounds No. 1} \times 0.25 \text{ manganese} + (460 \text{ pounds No. 2} \times 1.50 \text{ manganese}) + (250 \text{ pounds steel scrap} \times 0.75 \text{ manganese}) = (1000 \text{ pounds total charge} \times X \text{ per cent manganese}), \text{ that is:}$$

$$72.5 + 690 + 187.5 = 100 X$$

$$X = 0.95 \text{ per cent}$$

Allowing for the loss of manganese that takes place in melting in a cupola, this 0.95 per cent will probably be a shade under 0.80 when melted. The above mixture is therefore satisfactory and will give correct results. There will be a slight loss of silicon in the cupola, but the result will be well within the working limits. The above calculations can be worked out for any grades of pig iron by substituting percentages.

### THE GRAPHIC METHOD.

This method has been figured out on the above lines and reduced to a diagram, Fig. 16. For the diagram reproduced here the author is indebted to A. H. Jameson. It is figured for two grades of steel scrap, one containing 0.25 per cent of silicon and represented by the full line, and one containing 0.33 per cent of silicon and represented by the broken line.

The diagram may be used in a variety of ways. For instance, it may be used to give the amount of steel scrap that a certain pig iron will carry to give a desired per cent of silicon in the cupola. Knowing the per cent of silicon desired in the cupola, and the amount of scrap that is available, it will give the per cent of silicon the pig iron must contain. Given the per cent of silicon in the pig iron and the amount of scrap to be carried, it will give the resulting silicon in the cupola.

## CHAPTER IV

### OPERATION OF CONVERTER—BLOWING THE STEEL—HOW TO OVERCOME DIFFICULTIES DURING THE BLOW—ANALYSES OF CONVERTER CASTINGS

HAVING considered in the last chapter the calculations of the cupola charge, we will now follow its course through the subsequent procedure. In melting steel scrap along with pig iron in a cupola, provision must be made for hot melting and a higher ratio than 1 of coke to 7 of iron can scarcely be looked for. Cupola metal containing 25 per cent of steel scrap is liable to be sluggish, therefore plenty of coke must be used and an ample amount of blast. It is one of the most necessary things to insure good hot steel in the converter, that the cupola metal should be hot and clean. Some operators use a cupola of sufficient size to tap out the necessary 2 tons at one time, while others prefer a cupola holding only 1 ton at a time and make two taps per blow. This has its advantages, as the iron remaining a shorter time in contact with the bed of coke is less liable to absorb sulphur.

During the time the cupola has been charged and the iron melted, the converter has been prepared to receive the first charge of iron. It is necessary to get it to a high heat for this purpose, in fact the hotter it is the better. There are different ways of doing this and perhaps the most satisfactory is to make a coke fire and blow it with about 1 pound pressure from the blower for about two or three hours. Half a ton of coke is necessary and the converter is alternately blown for 15 minutes and turned upside down with a plate fastened over the mouth to retain the coke, and all tuyere box covers removed. This is to heat the bottom, which is not reached by the blast. It is essential that the bottom of the converter should be particularly hot. An oil burner or natural gas may be used, and is found satisfactory.

When the converter has been thoroughly heated the coke is dumped out into the ash pit and the unburnt portion recovered to be used in drying ladles, etc. The converter should be ready at exactly the same time as the iron is tapped out of the cupola. The iron is collected in a ladle and transferred to the converter, after which the latter is turned down until the iron just comes to the lip. It is then skimmed entirely free from slag

and this should be done before commencing each subsequent blow. The vessel is then turned up again and as it rises, the operator looks through the tuyeres from the back of the vessel and continues the rotation until the convex edge of the molten metal just appears over the edge of the tuyere. This is the most important point in the manipulation. The metal must be "up", but not in the tuyeres, and what constitutes "up" is a matter that takes some time to learn. It is well to use smoked glasses, or get the eyes accustomed to the color of the metal by watching it while being tapped out, poured into the converter and skimmed, otherwise it is comparatively easy to be deceived. When sure that the metal is exactly "up", the position of the converter is carefully noted.

For this purpose the writer uses an indicator, as illustrated in Fig. 17, which is simply a quadrant of sheet iron attached to the rotating gland on

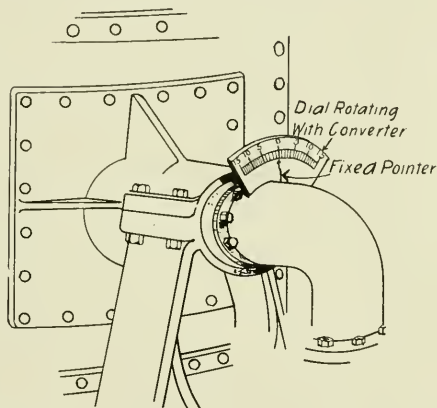


FIG. 17—INDICATOR FOR NOTING POSITION OF CONVERTER

the trunnion, and a fixed pointer. The indicator is graduated in degrees, both ways from the vertical.

When the converter is in the correct position for blowing, that is for obtaining the best results, the indicator should show about 5 to 9 degrees back from the vertical, that is the tuyeres should be inclined towards the surface of the metal and the direction of the blast should be very slightly downward upon it. Too great an angle would create too great a disturbance of the bath, which the Tropenas process is designed to obviate. If the angle appears too great or too small, a bull ladle of iron should be taken out or added as the case may be. The height of the iron in the ladle may then be noted and thereafter the cupola tender should have no difficulty in tapping out the correct amount.

After getting the proper amount of good, hot, clean iron in the converter, adjusting and noting the angle, the tuyere box covers are put on

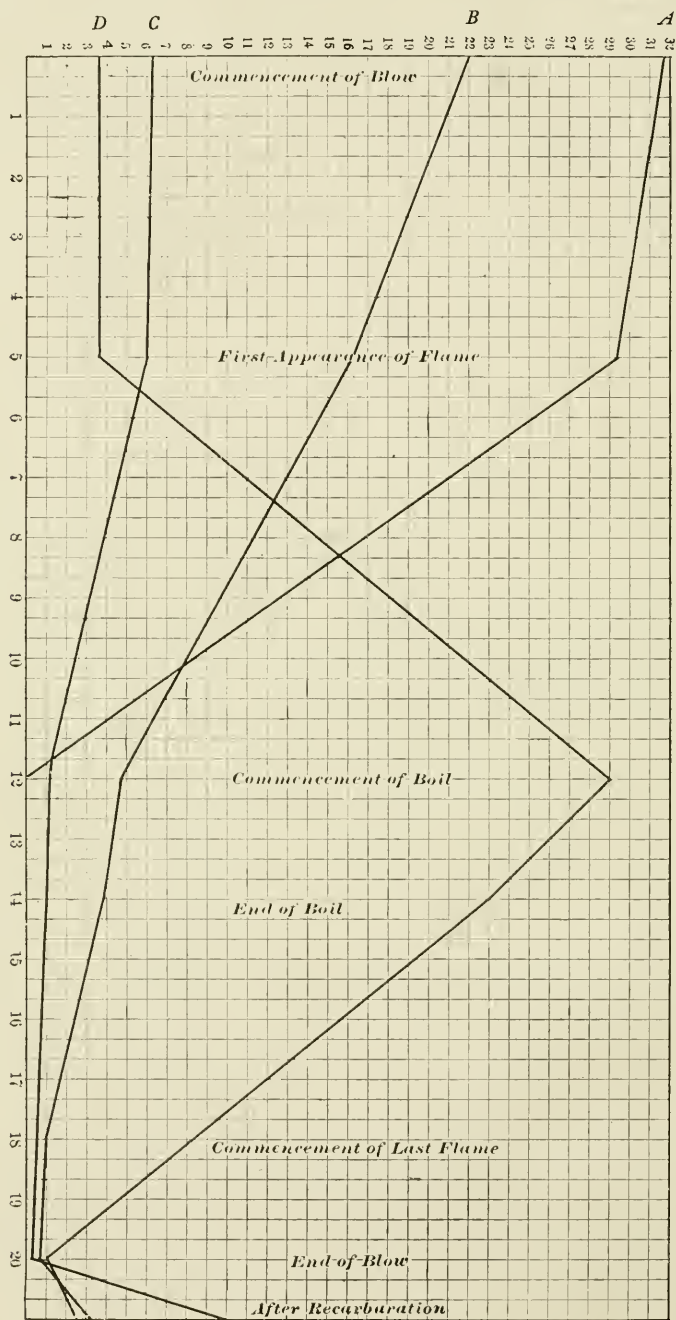


FIG. 18.—CURVES OF ELIMINATION OF ELEMENTS IN A TYPICAL BLOW; A IS FOR GRAPHITIC CARBON; B, SILICON; C, MANGANESE AND D, COMBINED CARBON



and fastened in position. Blast is then turned on by giving the customary signal of two short blasts on the whistle or bell communicating with the blower room, and the motor should be speeded to give 3 pounds on the mercury gage when the by-pass valve is entirely closed. A record of the exact time of starting the blow should be made.

### BLOWING THE STEEL.

At the beginning, sparks and smoke should come out of the mouth of the converter but very little flame. The sparks should be copious, large and scintillating, and light yellow in color, the smoke noticeable but not too voluminous, and not too dark brown in color. An experienced operator, by noting the appearance of the sparks and smoke, can tell during the first minute of the blow whether the silicon content is right, and if he is going to have a hot blow or if it will be necessary to doctor it up as it goes along. The sparks should all go up the chimney in parallel lines, not crossing or shooting out at different angles. In from three to five minutes the character of the sparks should change and become non-scintillating, and at the same time a flame should appear at the mouth of the converter. This is the time to open the upper tuyeres slightly, as the carbon is commencing to burn and extra oxygen is needed to complete its combustion and reap the full benefit from the heat generated. At the same time, the position of the converter should be advanced from 2 to 3 degrees, to compensate for the shrinkage in bulk due to the elimination of the impurities.

During the next four or five minutes the flame increases in brightness and volume until what is known as the "boil" occurs. The flame should be carefully watched and if there is a tendency to throw out any metal, the blast pressure should be reduced. In extreme cases it may be reduced to  $1\frac{1}{2}$  pounds, but this is as low as it is advisable to go. There will always be a certain amount of projection of slag, and this is immaterial unless it interferes with the observation of the flame.

Slippy blows are indicative of incorrect composition of metal, bad position of converter or too much blast. After maintaining its top position for one or two minutes, the flame dies down somewhat, and remains in a quiet condition for some minutes. The upper tuyeres may now be fully opened. The flame then rises again, becomes particularly bright and clear, and finally dies down for the last time with the evolution of copious brown smoke.

The blow should be turned down a few seconds before the brown smoke appears, as this smoke represents burning iron, which means waste of metal and ruination to the remainder. The operator throws over his controller, turning down the vessel into the horizontal position, and a second after signals one whistle to the engineer to stop the blower. At this stage there is in the converter a bath of practically pure iron at a temperature

well over 3,000 degrees Fahr. Fig. 18 gives the approximate curves of elimination of the elements in a typical blow. In order to recarburize it to the desired point, a weighed final addition of ferro-manganese, ferro-silicon, silicon-spiegel, or what not, is introduced. This may be added melted, in which case a small cupola or crucible furnace may be used, or it may be thrown in cold in lumps at the mouth of the converter immediately after turning down the blow, before the slag gets too hard. In this case the lumps must first be dipped in water so that the explosion of the vapor as they strike the hot slag will part it and allow the alloy to go entirely into the bath of metal. This latter method has been found by the author to be far the most useful and regular way of adding final additions. A special shaped core for skimming back the slag is fixed in the mouth of the converter and the metal is then ready to be tapped into the ladle.

#### HOW TO OVERCOME DIFFICULTIES IN BLOWING STEEL.

This is a description of a perfectly normal blow, which should take place in from 15 to 20 minutes. Unfortunately all blows are not normal, a great many conditions having to be harmonized to produce this result, some of which occasionally go wrong. Some of the difficulties that arise, with their cause and cure will be briefly touched upon. The flame should make its appearance at the mouth of the converter in from 3 to 5 minutes. If it comes in less time, it is a sign that the silicon content of the metal is too low and the probabilities are that the blow will not be as hot as desired, for the silicon is the fuel, and the chief source from which heat is derived. To offset this, when the flame makes its appearance, the converter should be advanced not more than two degrees and about 100 pounds of ferro-silicon in pig form thrown into the mouth of the converter. This has an astonishing effect and as it melts and gives up its silicon the blow becomes noticeably hotter. If the blow goes on for more than five minutes, at the same time the blast pressure remaining the same on the blast gage, it is a sign that the iron is either too high in silicon or it is too cold. If caused by too high silicon, there may not be very serious results except that the blow will certainly be very sloppy, the loss will be abnormally great, the blow will be longer and the resulting steel may be high in silicon on account of the fact that the carbon burns out before the silicon is entirely eliminated. If the latter is the case there is nothing to do but coax it along and dose it with silicon after the flame makes its appearance.

A frequent trouble due to various causes is the corking of the tuyeres. Its signs are an increase of pressure in the blast gage without any increase in the speed of the motor; a change in the directions of the sparks, some of which shoot out at right angles instead of all being parallel, and delay in the progress of the reactions. Stoppage of the tuyeres may cause serious troubles, such as cold blows, and violent reactions. The tuyeres are coked

by the formation of nozzles of slag on their extremities which tend to lengthen the tuyeres and may have openings in many directions, dispersing the blast and possibly permitting only a small amount of it to react on the metal. They are caused by cold metal, not setting the position of the vessel correctly, and not skimming it clean from slag at the commencement. When this corking is noticed it generally occurs before the flame makes its appearance, and the converter should be turned down, the blast shut off and the projections or nozzles knocked off with an iron bar. The blast is then started and the converter returned to its original position, when it will usually proceed all right. It may be necessary to repeat this procedure two or even three times. The result of corked tuyeres is almost invariably a sloppy blow if nothing worse.

#### ANALYSES OF CONVERTER CASTINGS.

In regard to the amount of final addition to be used a good deal could of course be written, also as to the materials to be used. In the first place, let us take the ordinary grades of simple or carbon steel. The analysis to be aimed at varies principally with the use to which the castings are to be put, and secondly to a less extent with the shape and weight of the piece. Speaking from the first standpoint it may be said that the analysis for ordinary machine or engine castings on which a good deal of machining has to be done should be carbon 0.25 to 0.30 per cent, silicon 0.25 to 0.30 per cent, manganese 0.60 to 0.75 per cent, and sulphur and phosphorus as low as possible, under 0.05 per cent.

For castings which will be subject to a greater amount of wear than ordinary, and for those which require a greater tensile strength such as levers, connecting rods and gears the carbon may be raised to from 0.35 to 0.40 per cent, and in cases where the castings are liable to "pull" on account of differences in section, great length, etc., the carbon may be raised to 0.50 per cent, silicon 0.30 per cent, and manganese up to 1.10 per cent. The castings last referred to will have to be annealed in all cases.

For the purpose of recarburizing to these points the common materials used are ferro-silicon containing about 12 per cent of silicon, silicon-spiegel containing about 10 per cent silicon and 20 per cent manganese, and ferro-manganese containing 80 per cent manganese. The amount to be used can easily be figured by an equation such as was used for calculating cupola charges, but it must be borne in mind that an excess of from 20 to 30 per cent of ferro-manganese must be used to compensate for that which goes to deoxidize the metal, and an excess of about 5 per cent of the calculated amount of ferro-silicon.

The action of the steel in the ladles is somewhat of an indication of its carbon content to the close observer. The softer and purer the steel the higher is the melting point and therefore in order to have it to remain

fluid in the ladle and allow it to free itself from gases, it needs to be superheated to a higher degree than the harder grades. It is more difficult to "dead melt" soft steel than hard steel, and soft castings are more difficult to run and are more liable to blow-holes. This is borne out by the fact that gray iron remains fluid in the ladle at a temperature where steel would set.

For making the special or alloy steels such as tungsten steel, chrome steel, manganese steel or nickel steel, either the ferro-alloys of these elements or the pure products of the electric furnace or aluminothermic process are used, and the amounts vary widely according to the purpose for which the castings are to be used. The materials produced by the aluminothermic process are very useful on account of their concentration, rendering it necessary to use only the minimum amount to produce the maximum effect, and by the freedom from carbon, etc., making control of the ultimate analysis more simple and certain.

## CHAPTER V

### HOT CRACKS IN STEEL CASTINGS AND HOW THEY MAY BE OVERCOME

**A**N attempt will be made in this chapter to outline the principal causes of one of the greatest difficulties that a steel founder has to contend with, and to suggest some means by which it may be overcome, at least partially. Cracks in steel castings are of two kinds, which differ in their appearance and cause very materially. Hot cracks take place at the time of solidification of the metal or very soon after; cold cracks are formed while the metal is below red heat. The former take the appearance of a tear, are very ragged and there is a sinking of the metal at the edges; they are generally quite wide and have a film of blue or black oxide on their fractured surfaces. Cold cracks, while they may be open occasionally, are generally very fine, clean cut as with a knife, and unless the castings are carefully inspected may sometimes escape observation. Ringing the castings with a hammer will often reveal the presence of cold cracks which are almost invisible. It is with the former, or hot cracks, that this chapter is intended to deal.

The two principal causes of hot cracks are obstructions to the free contraction of the metal, and unsuitable composition of the metal itself. First then look into the causes which may prevent the unrestricted contraction of the metal. They are chiefly the rigidity of the mold and the varying thicknesses of section of the casting. The mold has to be made sufficiently strong to stand the weight of the steel and the fluid pressure of the head of metal while it is being poured. Molds for steel castings are generally made in dry sand, which consists of silica sand mixed with a certain proportion of clay to bind it together. And though it is very weak in its green or damp condition, it becomes quite hard and firm after baking. The molds are faced with a wash made of silica flour and molasses water, which gives a very hard, refractory skin. It is therefore important that while the mold should be strong enough to stand all the pressure it is to receive, it should not be any stronger than is necessary for the above purpose. Means may be provided for making the mold stronger in some parts than others, for instance near the gate, where the cutting action is greatest. At these places the mold may be made of a stronger grade of sand, or if its shape allows, hard cores, or fire brick cut to shape, may be fitted in, to take the wear of the stream of metal. All square corners, both inside and outside,



should be amply filleted, and wherever a rib or a projecting arm of the pattern protrudes, the sand in its immediate vicinity should be loosened up by ramming in cinders, sharp sand or saw dust; or the mold can be cut away to within 2 or 3 inches of the pattern, after it has been dried, and the space filled in with burnt sand.

Another point to be attended to with the idea of reducing the danger of hot cracks is the drying of the molds. To produce the best results, a mold should be rather over-dried than under-dried, that is to say it should be almost but not quite burned. A mold that is only just dry is in the most rigid possible condition; it can be baked a good deal more and yet preserve sufficient strength to stand the wear and tear of pouring, and it will then offer much less resistance to the shrinkage of the metal. The ideal mold, as has been said before, consists of a hard refractory skin and a collapsible backing, which will give way as soon as the cooling skin of the casting has become sufficiently rigid to support itself, and begins to shrink. It is to the production of these conditions, as nearly as may be possible in practice, that foundrymen have to bend their efforts.

#### CORES FOR STEEL CASTINGS.

Defective construction of cores is another fruitful source of cracked castings. Coremaking is a branch of the steel foundry trade that does not receive the attention it merits. It is equally as important as the mold itself, calls for as much skill, and contributes equally to the success or failure. And yet we often find the coremaking relegated to a secondary place. Core sand mixtures should be as carefully studied as molding sand mixtures, and a great saving may be effected, not only in the matter of cracking, but in the cost of cleaning and the soundness of the castings by careful attention to this point. The same description applies to a core as to a mold—it should have a hard, smooth face, which will resist the cutting and fusing action of the metal, but it should crumble and fall out in the form of powder when burnt. Careful handling will permit the use of cores which seemingly are exceedingly delicate. As the author has previously stated, cores can be made of almost anything, provided the wash is satisfactory. When the core is rammed up it should have a good coat of a wash made of silica flour, Ceylon graphite and molasses water, and then put in the oven and baked until after scratching the skin the inside is thoroughly “rotten”. Then another coat of wash or two if necessary may be given, and the core is redried. It is surprising how strong this skin becomes, and it is no more than 1/32 inch thick.

In a great many cases a core has to stand much greater pressure than the mold itself, as for instance in a pipe or cylinder, where the metal is shrinking on the core from every direction. If the core is not collapsible

one or two things must happen—either it will crack the casting or the core will become so hard that its removal will be a very expensive and lengthy operation.

The second point, namely the composition of the metal itself, is equally important with the foregoing. Any conditions which tend to hot-shortness of the metal, which means brittleness above red heat, must be carefully avoided. The two principal elements found in common practice which have this tendency are sulphur and copper, and while their influence is not very great in the cold state of the steel, as the metal has to pass through the hot short period before cooling to the ordinary temperatures, it is important they should be kept as low as possible. Either, by itself, is dangerous, but the combination of the two is fatal. As a large proportion of Eastern iron is made from ores from the Cornwall district, a great deal of the scrap available, as well as the iron, has an appreciable content of copper, and it is therefore necessary to watch the sulphur most carefully, and care should be taken not to allow it to run over 0.045 per cent. This is done by selecting melting stock as low as possible in sulphur and running a high manganese, which will prevent increase of sulphur from the coke, etc., and tend to reduce it, if anything, by the formation of sulphide of manganese.

## CHAPTER VI

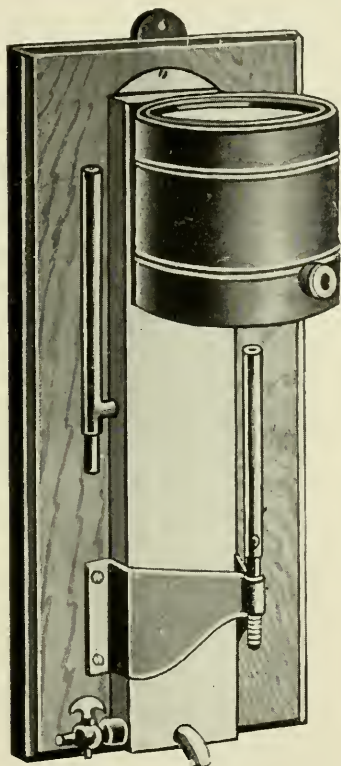
### THE STEEL FOUNDRY LABORATORY—ITS EQUIPMENT AND THE NECESSARY DETERMINATIONS

ONE of the essentials to success in the operation of a steel foundry is a well-equipped laboratory, where the analyses of all the raw materials entering into the manufacture, and also that of the finished product for checking purposes, can be made. Nowadays, when buying pig iron, coke, etc., it is customary to specify the analysis wanted, and most producers are willing to guarantee their materials within certain limits, supplying with each carload an analysis of that particular lot. At all events, it is supposed to be the analysis of that particular carload, but is more often the analysis of the cast or pile from which the car was loaded. As any cast of pig iron necessarily varies from one end to the other, it is wise to take a sample from each car and check the composition before using, to avoid mistakes.

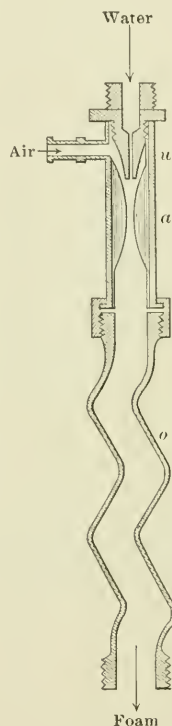
Steel is manufactured today on such close specifications and is required to be of such high quality, that it is impossible to get along without a laboratory, and the chemist is often the means of saving money to his employer by not only avoiding mistakes, but by locating trouble when it occurs without loss of time. The laboratory should be located where a north light is available and in some part of the works where the vibration caused by operation of heavy machinery, cranes, steam hammers, etc., will be felt as little as possible, for a great deal of the usefulness of the laboratory consists in the weighing of materials with exceeding accuracy, and the balance used is sensitive to the last degree. There should be two rooms, one not less than 18 feet square, and the other may be smaller, for the balance and the chemist's office. Around three sides of the larger room should run benches about 20 inches wide and the other side is left for the draught closet, muffle furnace and sink. The laboratory proper should be sheathed entirely in wood, as plaster is affected by the fumes and will fall into beakers, etc., with the result of spoiling estimations. There should, if possible, be a passage between the two rooms in order that through the protection of two doors, the balance may be preserved from the action of acid fumes. Under the benches should be drawers for apparatus that is not in constant use, filter papers, etc., and these drawers should be well fitted to exclude dust. It is very important that extreme cleanliness should be observed in all directions. The bench or table sup-

porting the balance should be very heavy and rigid, to minimize vibrations, as it is entirely impossible to weigh quickly or accurately on a balance that is not perfectly steady. An extra case of wood should be placed over the balance to further exclude dust.

Around the walls of the laboratory should be shelves at a convenient height above the benches, to hold the bottles containing re-agents for im-



A HANDY STILL



FILTER PUMP

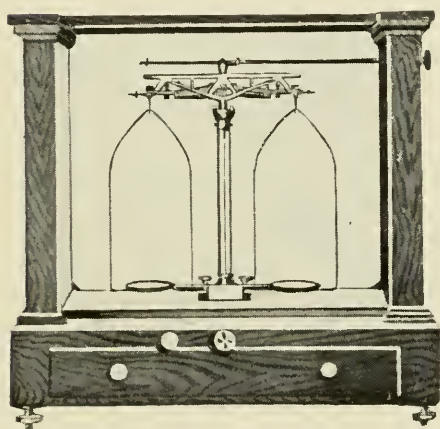
mediate use, and underneath the benches the large Winchester bottles of acids may conveniently be stored.

#### APPARATUS REQUIRED FOR MAKING ANALYSES.

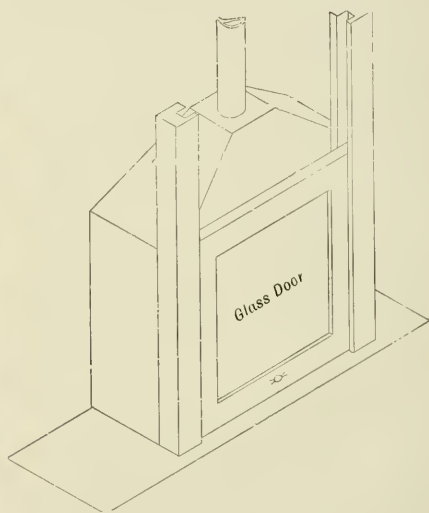
The following is a description of the principal apparatus needed for analyses of iron and steel materials, coke, sand, firebrick, etc., and while

more may be provided, or special apparatus used in some cases, the ordinary work of a steel works laboratory may be done with what is appended below:

The balance should be of the best quality, as it lasts practically forever and is responsible for the accuracy of results. It should have a short beam, not over 7 inches long, which should be of non-corrosive material, the longer beam balances make the time of weighing very much longer as they take so long to oscillate. A 7-inch beam will be sensitive to 1/10 milligram, which is sufficient for all practical purposes. All knife edges and planes should be of agate as the steel knife edges will rust in spite of all care that may be taken to prevent it. In the balance cases should be one or more small vessels containing strong sulphuric acid or chloride of



SHORT BEAM BALANCE



DRAUGHT CLOSET OR HOOD

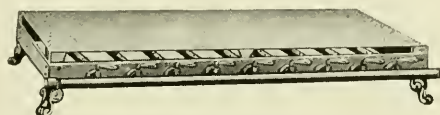
line to absorb the moisture in the balance case, and these should be changed from time to time. A small camel's hair brush should be used daily to dust off the balance. A set of weights is needed running from 50 grams to one milligram, and riders to hang on the graduated beam of the balance for subdivisions of 1 milligram. The pans of the balance should be large so as to accommodate small pieces of apparatus that may have to be weighed from time to time, but the metal pans should never be used for the actual weighing of materials, instead a small aluminum pan, counterpoised by a small weight should be used. It cannot be too strongly impressed that the balance must be scrupulously clean and in good condition, as this is where all accuracy will be destroyed at the outset.



Some form of a still is necessary, as pure water must be used in all determinations. There are many forms of stills, and a simple and effective one may be made by connecting a live steam pipe, if a steam line is handy, to a coil which can be kept cold by a stream of water from the laboratory service pipe. This is the cheapest way of obtaining a copious supply of pure water. If a steam pipe is not available, a self contained still must be provided, and one having a capacity of 20 or 25 gallons per day will be large enough.

For the heavy or gelatinous precipitates, it is necessary to have a filter pump to reduce the time of filtering. This consists simply of a specially shaped pipe, having a side inlet, attached to the water supply, and the water passing through the vertical pipe causes a powerful suction through the side pipe. This is connected to a filter flask, which is a conical flask having a side tube and a rubber cork fitted with a glass filter funnel. When filtering by means of the pump, it is well to introduce a platinum cone perforated with small holes, to prevent the suction from bursting the filter paper.

The muffle furnace is for incinerating precipitates, fusing refractory material, etc., and should be large enough to contain a muffle about 8 x 5 inches. It is heated by a row of five or six bunsen burners in a battery,



HOT PLATE

which may be controlled independently, so as to heat different parts of the furnace to different temperatures if desired.

The draught closet is an enclosure containing an iron plate with burners beneath, and is used for evaporations, solutions, and for the making of any reactions which give off fumes or gases, which would be unpleasant or dangerous. It should have a chimney with a good draught which may be increased by the introduction of a jet of compressed air blowing up the chimney. Practically all boiling of liquids is done in this closet although there are gas connections at intervals all around the benches. The laboratory is in this way kept cooler and more pleasant to work in. The plate should not be less than 24 inches long and 16 inches wide, as at times a great many beakers will be evaporating at the same time. The glass door slides in grooves and is counterbalanced by sash weights. The inside of the draught closet is preferably lined with tile.

The carbon bath is a piece of apparatus used for the determination of carbon by the color method and consists of a copper vessel about 7 inches in diameter and 7 inches high. It contains a support for the test tubes to be heated, in the form of two perforated discs held together with

a wire support. The test tubes are introduced into the holes and are by this means held in a vertical position while boiling, and prevented from being broken by the agitation of the water.

The remainder of the apparatus necessary, probably needs no special description and will be merely enumerated as follows:

- One air oven, 8x8x8 inches.
- One water bath, copper, with rings.
- One rough weighing balance, and weights, 10 grams to 500 grams.
- One test tube stand.
- Four bunsen burners.
- Two burette stands with clamps
- One burette stand with rings.
- Six iron tripods, 8 inches high.
- One wooden test tube holder.
- One iron mortar and pestle.
- One earthenware mortar and pestle.
- Two pair crucible tongs.
- One platinum crucible, 1 ounce capacity.
- One dozen porcelain crucibles,  $\frac{1}{2}$  ounce capacity.
- One 6-inch horseshoe magnet.
- Six thistle funnel tubes, 12 inches long.
- Six bulb tubes, 6 inches, fitted with two-hole rubber stoppers.
- Two 24-ounce flasks, fitted with two-hole rubber stoppers.
- One acid dropping bottle.
- One dozen 12-ounce beakers, best Bohemian glass.
- One dozen 10-ounce beakers, best Bohemian glass.
- One dozen 5-ounce beakers, best Bohemian glass.
- Four 40-ounce beakers, best Bohemian glass.
- One 100-ounce beaker, best Bohemian glass.
- Four 16-ounce conical flasks.
- Four 8-ounce conical flasks.
- Six 40-ounce conical flasks.
- Six 3-inch ribbed glass funnels.
- One 6-inch glass funnel.
- One 1,000 cubic centimeter graduated flask.
- One 500 cubic centimeter graduated flask.
- One 250 cubic centimeter graduated flask.
- One dessicator.
- One 100 cubic centimeter measuring glass.
- One 25 cubic centimeter measuring glass.
- Two dozen test tubes, 8 x 1 inches.
- Six dozen test tubes,  $\frac{5}{8}$  x 6 inches.

Six 4-inch watch glasses for beaker covers.  
Six 3-inch watch glasses.  
Six 2-inch watch glasses.  
One thermometer, up to 300 degrees Centigrade.  
One hydrometer, 1,000 to 2,000 specific gravity.  
Two burettes, 50 cubic centimeter capacity.  
Two burettes, 25 cubic centimeter capacity.  
One pipette, 100 cubic centimeter capacity.  
One pipette, 50 cubic centimeter capacity.  
One pipette, 25 cubic centimeter capacity.  
One pipette, 10 cubic centimeter capacity.  
One pipette, 5 cubic centimeter capacity.  
Two wooden filter stands.  
Six porcelain dishes, 6 inches diameter.  
Six porcelain dishes, 3 inches diameter.  
One platinum dish, 3 inches diameter.

The above list is not intended to include everything that may be conveniently provided, but it is sufficient for a laboratory employing one chemist and by its means he can make all the determinations he will ordinarily be called on to make. These are:

Carbon, by color method.

Graphitic carbon.

Manganese by color or gravimetric method in pig iron or steel, volumetric method in ferro-manganese, etc.

Silicon.

Sulphur.

Phosphorus.

Complete analyses of coke, limestone, sand, firebrick and clay.

The list of chemicals and re-agents necessary for the above determinations is not large, while they vary considerably according to the methods of estimation used. It is understood that all chemicals used for quantitative work must be chemically pure.

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